Water Measurement Units and Conversion Factors

Saleh Taghvaeian
Assistant Extension Specialist

Irrigation water management begins with knowing the quantity of water available. The purpose of this publication is to provide basic information on water measurement units and convenient conversion factors. Sometimes one will want to know only the volume of water used; while, at other times one will want to know the rate of flow. Conversion factors simplify changing from one unit of measurement to another.

Water Measurement Units

There are two conditions under which water is measured—water at rest and water in motion. Water at rest is measured in units of volume. Water in motion is measured in units of flow— unit of volume for a convenient time unit. It is important that the difference between a unit of volume and a unit of flow be kept in mind.

Volume Units

Water at rest; i.e., ponds, lakes, reservoirs, and in the soil, is measured in units of volume — gallon, cubic foot, acre-inch, and acre-foot.

Cubic Foot - The volume of water that would be held in a container one foot wide by one foot long by one foot deep.

Acre-Inch - The volume of water that would cover one acre (43,560 square feet) one inch deep.

Acre-Foot - The volume of water that would cover one acre one foot deep.

Flow Units

Water in motion; i.e., flowing in streams, canals, pipelines, and ditches, is measured in units of volume per unit of time—gallons per minute (gpm), cubic feet per second (cfs), acre-inches per hour and acre feet per day. Cubic feet per second, sometimes written second-feet (sec. ft. or cusec) is most commonly used for measuring flow of irrigation water moving by gravity from streams and reservoirs. Gallons per minute is most commonly used for measuring flow from pumps.

Cubic foot per second - The quantity of water equivalent to a stream one foot wide by one foot deep flowing with a velocity of one foot per second.

Gallon per minute - The quantity of water equivalent to a stream which will fill a gallon measure once each minute.

A flow of one cfs is approximately equal to either 450 gpm, one acre-inch per hour, or two acre-feet per day (24 hours).

Conversion Factors

The following equivalents are useful for converting from one unit to another and for calculating volumes from flow units.

Volume Units

One gallon
= 231 cubic inches
= 0.13368 cubic foot weighs approximately 8.33 pounds

One cubic foot
= 1,728 cubic inches
= 7.481 gallons (7.5 for ordinary calculations) weights 62.4 pounds (62.5 for ordinary calculations)

One acre-inch
= 3,630 cubic feet
= 27,154 gallons (27,200 for ordinary calculations)
= $1/12$ acre-foot weighs approximately 113.1 tons

One acre-foot
= 43,560 cubic feet
= 325,851 gallons
= 12 acre-inches weighs approximately 1,357 tons

Flow Units

One gallon per minute
= 0.00223 (approximately $1/450$) cubic foot per second
= 0.00221 acre-inch per hour
= 0.00442 acre-foot per (24 hour) day
= 1 acre-inch in 452.6 hours (450 for ordinary calculations)
= 1 acre-foot in 226.3 days

One cubic foot per second
= 448.83 gallons per minute (450 for ordinary calculations)
= 1 acre-inch in 1 hour and 30 seconds (1 hour for ordinary calculations)
= 1 acre-foot in 12 hours and 6 minutes (12 hours for ordinary calculations)
= 1.984 acre-feet per (24 hours) day (2 acre-feet for ordinary calculations)

Million gallons per day (mgd)
= 694.4 gallons per minute (695 for ordinary calculations)
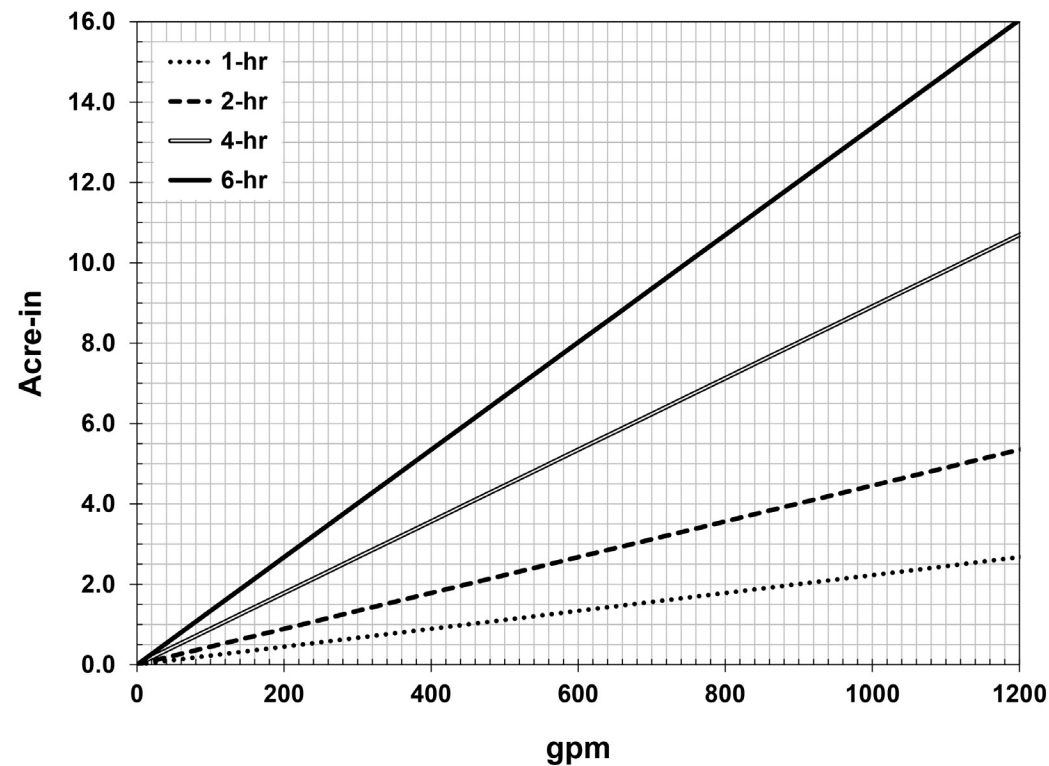= 1.547 cubic feet per second (1.5 for ordinary calculations)

Figure 1. Conversion from gpm to Acre-in for different water application durations.
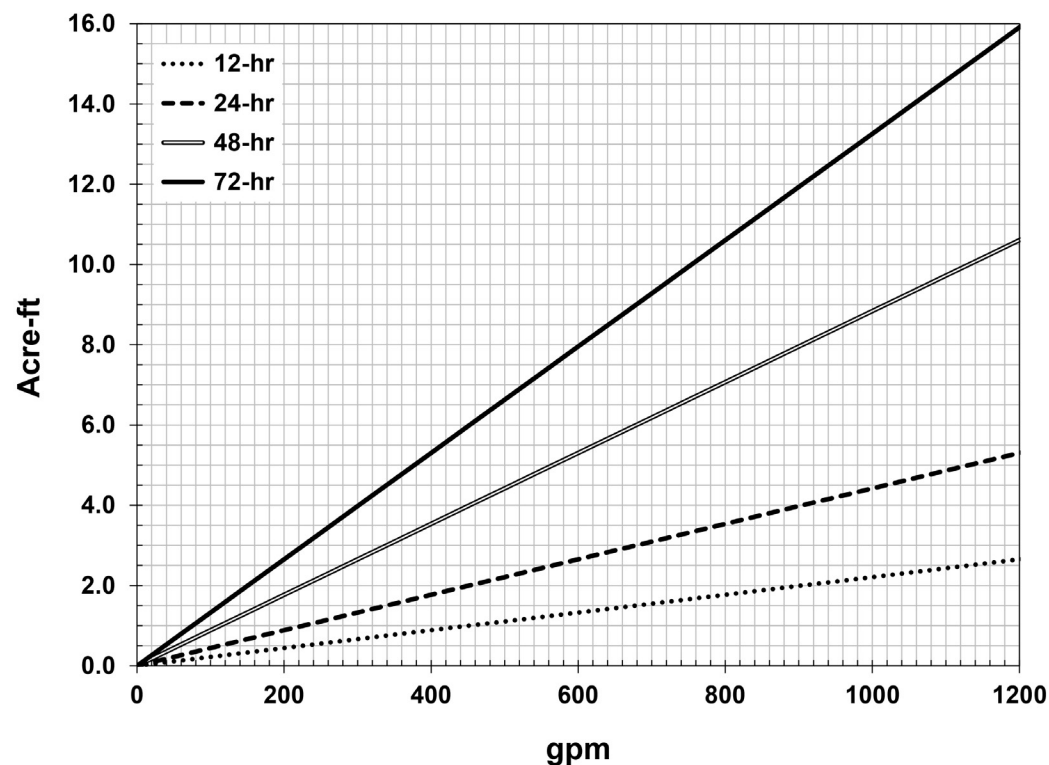

Figure 2. Conversion from gpm to Acre-ft for different water application durations.

Conversion Table.

To convert from:	To:	Multiply by:
Cubic-ft	Gallons	7.5
Acre-in	Cubic-ft	3,630
Acre-ft	Cubic-ft	43,560
Acre-ft	Acre-in	12
cfs	gpm	450
Acre-in per hr	cfs	1
Acre-ft per hr	cfs	12

Using Conversion Table

To convert from the units in the first column to units in the second column multiply the value in the first unit by the factor provided in the third column. To go in opposite direction and convert from the units in the second column to units in the first column simply divide by the number in the third column.

The above table can be also used to convert from a flow unit to a volume unit and vice-versa, or to estimate the operating hours required to deliver a desired volume of water. The following examples and graphs provide a better understanding on how such conversions can be carried out.

Example 1. The average daily crop water use during the month of June was 0.45 inches at a 60-acre corn field in Oklahoma Panhandle. What is the total volume of water used up by this field in June?
- *Step 1.* The total depth of water use during June was 0.45 × 30 (days) = 13.5 inches.
- *Step 2.* The total volume of water use was 13.5 × 60 (acres) = 810 acre-in.
- *Step 3.* This volume is equal to 2,940,300 cubic-ft (row 2 in conversion table) or 22,052,250 gallons (row 1 in conversion table).

Example 2. How many hours a well yielding 400 gpm should operate to fill an irrigation pond that is 150 ft long, 100 ft wide, and 10 ft deep?
- *Step 1.* The volume of this pond is 150 × 100 × 10 = 150,000 cubic-ft. This volume is equal to 1,125,000 gallons (row 1 in conversion table).
- *Step 2.* A well with 400 gpm should operate 2,813 minutes (1,125,000 ÷ 400) to fill the pond. This period of time is equal to about 47 hours (two days).
* In this example the seepage from the pond is ignored. Longer times will be required depending on the magnitude of seepage.

Example 3. What would be the volume of applied water if a well yielding 700 gpm operates for 24 hours?
Using conversion table:
- *Step 3.* Look at row 5 in conversion table. We want to convert gpm to cfs (moving from right to left in table), thus we divide 700 gpm by 450, obtaining 1.55 cfs.
- *Step 4.* Based on row 6 in conversion table, 1.55 cfs is equal to 1.0 acre-in for each hour of water application.
- *Step 5.* If the well operates for 24 hours, the total volume of applied water will be 1.55 × 24 = 37 acre-inch or about 3 acre-feet.

Using conversion graphs:
- *Step 1.* The volume of 3 acre-feet can be read from graph 2, knowing the well capacity (700 gpm) and duration of operation (24 hr).

Example 4. How many cubic feet per second are required to make a 4 inch gross application on 40 acres of land in 72 hours?
Using conversion table:
- *Step 1.* The total required volume of water is 4 × 40 = 160 acre-inch.
- *Step 2.* Applying this amount during a 72-hr period requires a flow rate of 160 ÷ 72 = 2.22 acre-in per hour.
- *Step 3.* Based on row 6 in the conversion table, a flow rate of 2.22 acre-inch per hour is equal to the same amount in cfs (2.22).

Using conversion graphs:
- *Step 1.* The total volume of 160 acre-in is equal to 13.33 acre-feet (row 4 in conversion table).
- *Step 2.* Based on graph 2, applying this amount of water during a 72 hour period requires 1,000 gpm.
- *Step 3.* 1,000 gpm is equal to 2.22 cfs (1,000 ÷ 450 = 2.22, row 5 in conversion table).

Conversion between English and Metric Units

Agricultural producers in many parts of the world use Metric (also called SI) units in their routine water measurements. The most commonly-used volume units in Metric system include liter, cubic meter, and hectare-millimeter, while common flow units are liter per minute (lpm) and cubic meter per second (cms). The following conversion table can be used to convert between English and Metric units.

English/Metric Conversion Table.

To convert from:	To:	Multiply by:
Gallons	Liters	3.8
Cubic-meter	Cubic-ft	35.3
Cubic-ft	Liters	28.3
Acre-in	Hectare-mm	10.3
gpm	lpm	3.8
cfs	lpm	1700
cms	cfs	35.3

Irrigation water management does begin with knowing how much water is available and involves some arithmetic. The most common mistake when working with water measurement units is to accidentally substitute one flow unit or volume unit for another without proper conversion. Usually the final answer appears obviously wrong; however, this is not always true. When checking your arithmetic, also check the measurement unit to see they are correct.